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11 August 1980

West Europe Report

SCIENCE AND TECHNOLOGY

(FOUO 9/80)

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WEST EUROPE REPORT

SCIENCE AND TECHNOLOGY

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INDUSTRIAL TECHNOLOGY

AUTOMATION OF STEEL PLANTS DESCRIBED

Duesseldorf STAHL UND EISEN in German 11 Feb 80 pp 112-118

[Article by Hans-Georg Scheurer and Emil Elsner, Baden-Baden]

[Text] UHP arc furnaces work economically only when the efficiency of the electric power is high enough. It becomes more and more difficult to understand the interaction of the complex operating and controlling processes and to take the right decision within the shortest time. For this, process data processing is an efficient aid to optimize and coordinate the individual operations.

Korf-Stahl AG in cooperation with AEG/Telefunken have developed an automation system with process computers for electric steel plants. It comprises four functions: information and reports, thermal process control, metallugical process control, and work flow control.

The fast development in the field of semiconductor technology, especially in the field of microprocessors and microcomputers, in conjunction with the price advantages of these elements enables the use of microcomputers also for solving all automation problems in the steel plant. The microcomputers developed by Korf-Stahl AG with their automation functions are described. These microcomputers allow in conjunction with a simple superimposed process computer to build up gradually an overall automation system.

The electric arc furnace has established itself as an important smelting unit for scrap and sponge iron. New furnaces are equipped with specific transformer powers of 1 MVA/t steel. In addition, the smelting power of the furnaces is increased by using oil-, (gas-)/oxygen burners and/or oxygen lances. Such furnaces can operate economically only when the electrical power is utilized with sufficient efficiency. Down times and idle times must be reduced to a minimum. An essential precondition for this is to optimize and coordinate the following processes:

Selection of scrap for the steel type that is being smelted and feeding the scrap into the furnace.

Admixture of additives and auxiliary components.
Utilization according to the power specified in the electrical current contract.
Longest possible utilization of the highest power stage of the transformer. It here appears to make sense to change the current at the highest voltage stage, and consequently the length of the arc, in accord with the smelting condition of the furnace.
A suitable energy input with a flat bath.
Additional energy input when oil-, (gas-)/oxygen burners are used. The use of burners might also be viewed in combination with the electrical current contract (high current rate) and with the operations organization (speeding up a furnace for better utilization of continuous casting plants).
Logging and recording important operating parameters of the continuous casting plants, for coordination with the smelting operation.
Utilization of oxygen lances, taking into account the amount of carbon that is to be oxidized out and the heat generated thereby.

High efficiencies are achieved especially in Japan by using well-trained and disciplined smelting personnel in combination with a flexible cooperative union. However, these Japanese circumstances are scarcely transferable to Western industrial countries. In addition, it is becoming increasingly more difficult for human operators to understand the interaction of these complex processes and to make the correct decisions for the next working step, in the shortest possible time.

For this reason, it is appropriate to fall back on the assistance that is provided by process data processing.

Automation With Process Computers

When checking actually operating automation systems at the beginning of the seventies, it was determined that there was no suitable system for the mass production of steel in electric steel plants. The center of interest for automation lay in optimizing the load with maximum monitoring and with alloy calculations. For this reason, in the year 1972, we collaborated with AEG Telefunken to develop a proper system. A metallurgical model was the beginning, and this model was tested in off-line operation for several months, at the steel plant of Baden Steel Plant AG.

The results of these tests indicated that automation of electric steel plants was possible and sensible. The cost advantage achieved in off-line operation, by this model alone, was 1 DM/t steel.

These results were the occasion for an overall attack on automating electric steel plants by process computers. The resulting automation system is composed of the following four task areas (Figure 1):

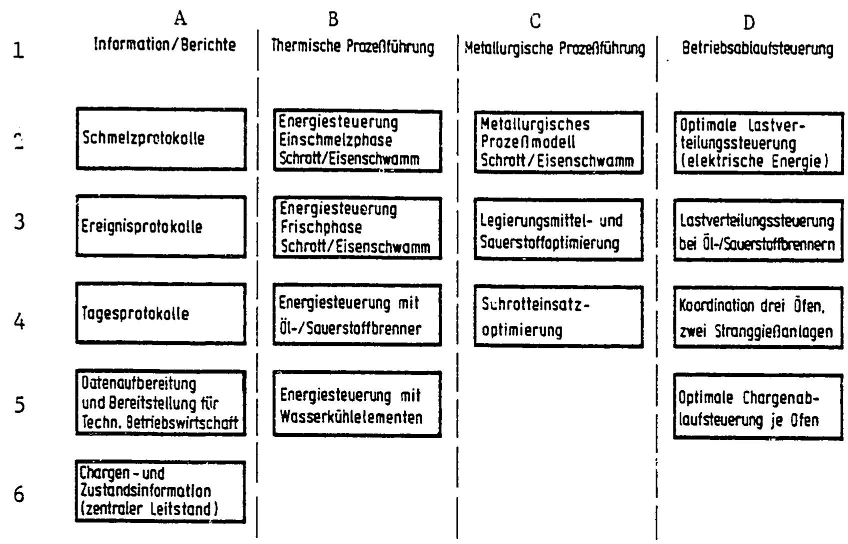

Figure 1. Tasks of process automation in the steelmaking plant

A1 Information/report
B1 Thermal process control
C1 Metallurgical process control
D1 Work flow control
A2 Smelting log
B2 Energy control, smelting phase, scrap/sponge iron
C2 Metallurgical process model, scrap/sponge iron
D2 Optimal load distribution control (electrical energy)
A3 Logging of events
B3 Energy control, refining phase, scrap/sponge iron
C3 Alloying agents and oxygen optimization
D3 Load distribution control with oil/oxygen burners
A4 Daily log
B4 Energy control with oil/oxygen burners
C4 Optimization of scrap use
D4 Coordination of three furnaces, two continuous casting systems
A5 Data preparation, and furnishing data for technical operations
B5 Energy control with water cooling elements
D5 Optimum charge load control per furnace
A6 Charge and status information (central management)

1. Information/Reports

The computer collects and stores all the important data of the smelting operation. Either automatically or upon demand, it informs all parties interested in the smelting process, in the form of directives, reports, or data transmission. Such parties may include the smelting personnel, the management of the steel plant, the factory maintenance personnel, or technical operations (Figures 2 and 3).

The objectives for which this information system strives are the following:

Better and more objective information concerning the behavior of the charges and the condition of the furnace;
relieving the personnel from writing work;
easier interpretability of the collected data;
supporting the smeling personnel in making necessary decisions.

2. Thermal Process Control

The supply of the available energy (electrical energy, thermal energy) is controlled automatically by the computer, independent of the operating personnel, taking into account the charge input, the loss power of the furnace, and the optimum operating point.

The objective here is to reduce specific energy consumption, to reduce levelling times, and to reduce charging times.

3. Metallurgical Process Control

The computer takes overa all the necessary metallurgical decisions, such as scrap input, alloys, oxygen blowing times, in dependence on the type of steel that is being smelted. It either transmits these decisions as instructions to the smelting personnel or it inputs them directly into a subordinate, automatic charging system. In contrast to other automation systems, no simple alloying calculation is here performed, but all metallurgical decisions are performed by an adaptive process model, that means a model that automatically adapts itself to changing operating points.

In this way, cost-optimal scrap and alloy additives are achieved, the number of specimens is reduced, and the charging time is shortened.

4. Work Flow Control

The computer should distribute the available quantities of energy (electrical and/or thermal) automatically and optimally to the existing furnaces. Furthermore, it should automatically perform important organizational decisions concerned with the work flow, such as, for example, the coordination of the furnace/continuous casting system or the use possibilities of oil/oxygen burners.

The significance of work flow control is to utilize the existing capacity and energy quantities in an optimum manner and thereby to achieve maximum throughput at minimum cost.

Figure 4 schematically shows the hardware configuration that has been installed at the BFW (Baden Steel Plants). It can be seen that, for each

[redacted]

furnace, there is an operating desk with a telex and that the process computer system consists of a double computer, each with an external memory, and the required peripheral equipment. Both computers (Figure 5) are connected with one another and with the two external memories. This facilitates relatively easy data exchange between the computers. The process computer ZE 1 has direct access to the process peripheral equipment, and is used to exchange the necessary information with the process and operating personnel. The process computer ZE 2 is used as a disposition or coordination computer. For example, all process models and the coordination of furnace/casting operations run in this computer.

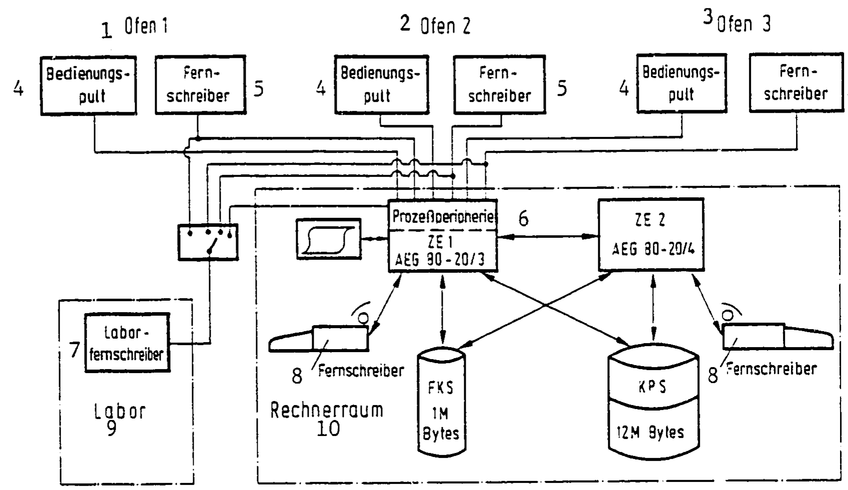

Figure 4. Computer hardware

1 furnace 1
2 furnace 2
3 furnace 3
4 operating desk
5 telex
6 process peripheral equipment
7 laboratory telex
8 telex
9 laboratory
10 computer room

The automation programs, that have been implemented by now, made possible savings through the following means:

better utilization of the available electrical energy;
reduction of specific energy demands per ton of steel;
reduction of charging time and consequently increasing product output;
saving of electrodes.

The implementation of further automation stages by the end of this year promises additional cost advantages by reducing the charging time and by savings in alloys.

Automation With Microcomputers

In the area of semiconductor technology and especially the area of microprocessors and microcomputers, major technological advances were made in recent years, especially under the stimulus of space research. At the same time, the costs and prices for these components were significantly reduced, as the following figures will clarify:

A microprocessor crystal with 25 mm^2 surface today exercises the function of several thousand transistors.

Computer systems which still cost 1.5 million DM in 1950, can today be obtained - with the same capability - for about 15000 DM.

Because of the great flexibility of these components and their associated manifold use capabilities, the use of microcomputers in electric steel plants has been investigated for about a year and a half. Up to now, the following devices have been developed:

KOM 1100 for operations monitoring of electric arc furnaces;
KOM 1202 for controlling the oil/oxygen burners;
KOM 1301 for controlling the water cooling systems.

By the end of 1979, the following devices are supposed to be developed:

KOM 1500 for optimum load distribution;
KOM 2450 for automating continuous casting systems and for coordinating furnace/casting operations.

Further automation systems based on microcomputers are in preparation.

The aims of the microcomputer devices already in existence can be described as follows:

KOM 1100.

The microcomputer device KOM 1100 (Figure 6) is used to monitor the electric variables of arc furnaces and to adjust and monitor the electrode control. In another expansion stage, and by furnishing the necessary measurement signals (for example pressure of the support arms), this device can also be used as an electrode scrap protection device. The functions of the device are the following:

furnishing all the information for the furnace adjustment;
monitoring the furnace adjustment by measurable and specially calculated electrical data (for example, arc voltage, wear factor, etc.);
fast, logged information concerning deviation from optimal furnace adjustment and concerning conditions where the adjustable alarm values are being exceeded;
monitoring the electrode control for full functional capability;
regular logging of electrical measurement data of interest and of data calculated therefrom;
determining and outputting these variables for each transformer stage and phase;
calculating maximum, minimum, averages of all variables for freely adjustable time intervals;
automatic output of status logs concerning the furnace adjustment after each charge.

By using the possibilities inherent in this microcomputer, savings of solid fuels up to ten percent and savings of energy up to 5 kWh/t billet are possible. If this device is also used as an electrode scrap protection device, a major portion of the electrode rupture can be saved. The scrap rate normally is about five to ten percent of the electrode consumption.

KOM 1202

The microcomputer device KOM 1202 (Figure 7) is used to control the oil-oxygen burner and as an interface for superposed load optimization. It has the following functions:

automatic sequence control when switching the oil-oxygen burner on and off;
monitoring the oil-oxygen burner for correct functioning and for possible shut-down of the burner;
automatic shut-down of the burner after an adjustable burning time;
constant display of the residual burning time;
interface with superposed automation systems (for example process computer, microcomputer).

This microcomputer offers a space-saving and problem-free control of the oil-oxygen burner. In addition, it forms the interface to other automation systems.

KOM 1301

KOM 1301 is a microcomputer device for the completely automatic control of the water quantity per cooling box, in dependence on the water temperature at the cooling box exit. The regulation is effected according to the PID-speed algorithm with a series-connected three-point control (hysteresis). The device exercises the following functions:

- temperature-dependent control of the water quantity for each cooling box and furnace;
- monitoring the water exit temperature and outputting alarm messages (lamp, horn, printer), if the temperature of the cooling box exceeds the adjustable alarm limits;
- monitoring the valve adjustment for each cooling box and outputting alarm messages (lamp, horn, printer), if the valve position of a box falls below an adjustable alarm limit;
- outputting alarm messages, logs of measured data, and survey logs on a built-in thermoprinter
- determining the thermal furnace load;
- interface for a superposed automation system (microcomputer or process computer).

By means of the KOM 1301, the cooling water quantity, which normally amounts to 100 to 150 $1/(m^2 \cdot min)$, can be reduced to an average of 50 $1/(m^2 \cdot min)$. It is therefore particularly deployed in plants with a deficiency of cooling water. It can also be used as a supplement to the electrical data for furnace control, which are provided by the KOM 1100 microcomputer. In this function, it evaluates the thermal furnace loads.

KOM 1500

The KOM 1500 microcomputer system is used to monitor and control the maximum energy demand of one or more loads and to assure an optimum and priority-dependent energy distribution among the various loads. This system has the function of taking care that the maximum energy supply is not exceeded within a prescribed and adjustable monitoring time (for example 15, 30, 60 minutes), and on the other hand is utilized as completely as possible. The necessary switching actions (switching on and switching off) of the switchable energy loads should here be kept to a minimum.

The microcomputer system has a modular structure. It therefore allows optimal adaptation to the given circumstances of various energy loads and can be used universally. The entire system is comprised of one or two supervening microcomputers KOM 1500.01 (Master), each with a microcomputer device KOM 1500.02 (Slave) for the individual loads (for example electric arc furnaces). The functions of the system are as follows:

- determining the individual energy consumption and energy behavior of individual arc furnaces and base load;
- determining the optimum switch-off strategy of individual loads;
- switching on and off or reducing (with subswitches) the individual load according to an optimum switch-off strategy that has been determined in advance;
- monitoring the energy and the time pulses.

With this device, average efficiencies of electrical energy are achieved, which exceed 92 percent.

KOM 2450

The KOM 2450 microcomputer device serves both to acquire data and interference data and for automating billet continuous casting systems. It makes possible the following functions:

Automatic acquisition and processing of suitable signals and measurement data;
Through an operating console, it is possible to input data which cannot be acquired automatically;
Preparation of data where necessary for coordinating the furnace/casting operation and for furnishing casting reports, and transmission of such data to a supervening automation system (for example process computer);
Partial automation of the continuous casting system through quality- and temperature-dependent control of the cooling water quantity, and possible control of the speed on the basis of prescribed flow-diagrams;
Connection of pyrometers to measure the surface temperature of the casting. This makes possible a direct, temperature-dependent control of the continuous casting system.

This microcomputer therefore delivers to the process computer all the data which the latter requires to coordinate the furnace and the continuous casting system. At the same time, the microcomputer suitably adjusts the quantities of cooling water in accord with the type of steel and the casting temperature. It monitors the result by acquiring the casting temperature perpendicular to and along the direction of the casting. Unequal cooling effects, which could result, for example, by a twisted ingot or plugged spray nozzles, are here sensed and indicated. Likewise, continuous calculation of the crater depth is also possible.

Automation With Microcomputers and Process Computers

With these and other microcomputers, and with a supervening, simple process computer, it is possible to implement an overall automation system, according to Figure 8. The entire automation system is constructed according to modern data processing technology. It consists of several decentralized microcomputer modules. Through this decentralized structure, the following advantages, among others, are achieved:

The entire automation system can be built step-by-step and with relatively low initial cost (a large and expensive process computer is not immediately required).

Because of the modular structure, the optimal automation system can be selected for each steel plant, without unnecessary expenditures for unnecessary automation tasks.

Since the connection between the individual modules and the process computer consists only of serial data transmission paths (two or four strands), additional kilometers of cable and the corresponding mounting costs are thereby saved.

The normally required, expensive process computer system (double computer, multiple storage, expensive process and data peripheral equipment) shrinks to a relatively inexpensive central unit with a simple data peripheral unit and no kind of process peripheral equipment.

The overall system is significantly less susceptible to troubles and can continue to operate at least partially, even if individual components fail.

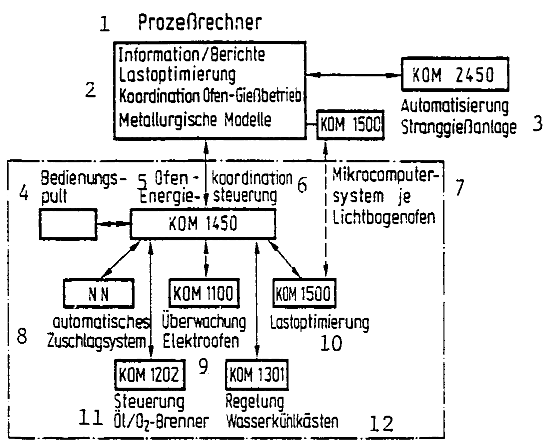

Figure 8 Automation concept with process computer and microcomputers

1 process computer
2 information/reports, load acquisition, coordination of furnace and casting operations, metallurgical models
3 automation of continuous casting system
4 operating desk
5 furnace coordination
6 energy control
7 microcomputer system for each arc furnace
8 automatic additive system
9 monitoring the electrodes
10 load optimization
11 control of oil/O_2 burner
12 control of water cooling boxes

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INDUSTRIAL TECHNOLOGY

NEW PROCESS FOR CHEAPER PRODUCTION OF PIG IRON DESCRIBED

Duesseldorf STAHL UND EISEN in German 10 Mar 80 pp 220-224

/Article by Per Collin, Falun (Sweden), and Hans Stickler, Västeras (Sweden)/

/Text/ Summary

The ELRED Process is a new method for producing liquid iron by a two-stage reduction of iron ore concentrates with coal. In the first stage, fine-grained concentrates are prereduced in a fast fluidized bed with gas generated from coal powder and air in the same bed. In the second stage, the fine-grained product from the first stage undergoes final reduction and smelting to iron in the plasma beneath the electrode in a d.c. arc furnace.

An important feature of the process is that both the concentrates and the coal can be used without previous agglomeration in a sintering plant or coking in a coking plant. The combustible flue gases from both reduction stages are cleaned and utilized to generate electricity in a combined-cycle power plant. The electrical energy obtained in this way covers the power requirements of the process and a small surplus can also be fed to the mains supply.

In view of the absence of a sintering plant and a coking plant and of the low energy cost, it is estimated that liquid iron can be produced at a cost approximately 20 per cent below that of pig iron from a modern blast furnace of the same capacity. Further, the environmental load is considerably lower, since a sintering plant and a coking plant are not necessary. The new process is also competitive in terms of cost when used in small plants.

The ELRED method is a new method for producing pig iron from iron ore concentrate by two-stage reduction with anthracite. In the first stage, fine-grained concentrate is prereduced in a fast fluidized bed. In the second stage, the fine-grained product is completely reduced in a d.c. arc furnace.

The method has the great advantage that both iron ore and anthracite can be used in powdered form and need not be first pretreated by sintering or coking.

The combustible flue gases from both process steps are converted into electrical power in a combined gas-steam power plant. The electrical power generated thereby covers the entire consumption of the system and even yields an excess, which can be fed into the mains.

Because of its low investment costs, resulting from the omission of a sintering plant and coking plant, and because of the low-energy costs, resulting from using simple anthracite coal, it is expected that production costs for ELRED pig iron will be about 20 per cent less than those of blast furnace iron. Furthermore, the lack of a sintering plant and coking plant is very favorable for the environment, and is already economical even in smaller units.

History of the Project

The basic patents on the ELRED method were applied for in the year 1979 by Stora Kopparberg. In the following year, Stora and the ASEA agreed to collaborate in theoretical and experimental studies. At the same time, the experimental work on both process stages was begun.

In the years 1973 and 1974, the first experiments with reduction in a fast fluidized bed were performed at Lurgi Chemistry and Metallurgical Engineering Ltd., Frankfurt (Main). In 1975, a collaboration contract was signed between Lurgi and Stora/ASEA. A prereduction system was set up on a small scale, on the property of the Central Research and Development Division of ASEA, Västeras (Figure 1). Since the end of 1976, this installation has been used for comprehensive experiments.

In parallel to the experiments with prereduction, experiments with the final reduction were performed in a d.c. arc furnace, which ASEA originally developed for smelting scrap steel. The preliminary experiments took place at the Metallurgical Research Institute Lulea, and the main experiments were performed in the Domnarvet Steel Plant, in a 30-ton arc furance, which had been converted to d.c. operation (Figure 2). The experiments were concluded in the fall of 1979.

The development costs for the ELRED method, by the end of 1979, have been about 15 million DM, and were covered entirely by Stora and ASEA. A considerable number of patents was applied for in many countries, and these patents cover the method as well as the installation.

A joint enterprise, the ELRED Engineering AB, Västeras, was formed to further develop and to market the method.

Work Flow

Figure 3 shows a schematic flow chart of the ELRED method. The basis idea of this method is a two-stage reduction of iron ore, namely a first prereduction of the ore with an excess of carbon, to form a solid, fine-grain material with a high metallic content, but also with a certain carbon content, and secondly, the final reduction and the smelting of this material with electrical power. The flue gases of both stages are used to generate electricity.

Since thermodynamic equilibrium cannot be entirely reached, the process gases generate more electrical energy than can be consumed in the final reduction stage. A certain excess occurs, which is fed into the mains.

The net energy consumption per ton of pig iron in the ELRED process is about 15,500 MJ (3.7Gcal) with a power plant efficiency of 33 percent. This value therefore is not significantly different from those of large blast furnaces. However, the energy costs per ton of pig iron are here considerably lower than in the blast furnace process, because of the much lower energy unit costs for the coal that is used in the process, in comparison to the corresponding costs for the coke that is required in the blast furnace process.

Raw Materials

Anthracite of variable quality can be used as the energy medium, for example anthracite or still better bituminous types of coal. The coal is preferably obtained in the form of small coal, is ground to an average granularity of 0.2 to 0.3 mm, and is dried before being blown into the fluidized bed.

The ore concentrate used in the ELRED method should be fine grain (average grain size < 0.1 mm) and, if possible, should have an iron content above 65 percent. Phosphorus-containing iron ore can also be used.

The Prereduction Stage

The prereduction (Figure 4) occurs under pressure in a fast fluidized bed. This fluidized bed differs from a classical one primarily by the fact that the gas speed is considerably higher. The excess of coal in the layer and the high gas speed prevent the ore powder from baking together. Because of the strong agitation of the material in the reactor, the temperature is very uniform. Coal dust and air are blown directly into the reactor, and there they generate the temperature required for the reduction (950 to 1,000°C). At the same time, they provide the carbon

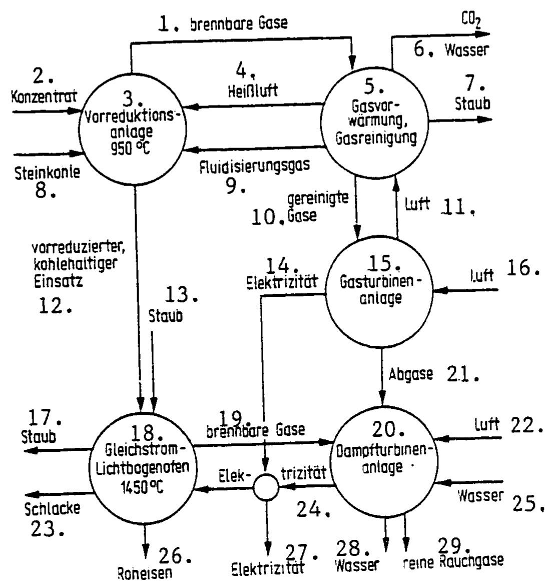

Figure 3: Flow Chart of the ELRED Process

Key:

1. Combustible gases
2. Concentrate
3. Prereduction system 950°C
4. Hot air
5. Gas heating, gas purification
6. Water
7. Dust
8. Anthracite coal
9. Fluidizing gas
10. Purified gases
11. Air
12. Prereduced, carbon-containing charge
13. Dust
14. Electricity
15. Gas turbine system
16. Air
17. Dust
18. DC arc furnace 1450°C
19. Combustible gases
20. Steam turbine system
21. Exhaust gases
22. Air
23. Slag
24. Electricity
25. Water
26. Pig iron
27. Electricity
28. Water
29. Pure flue gases

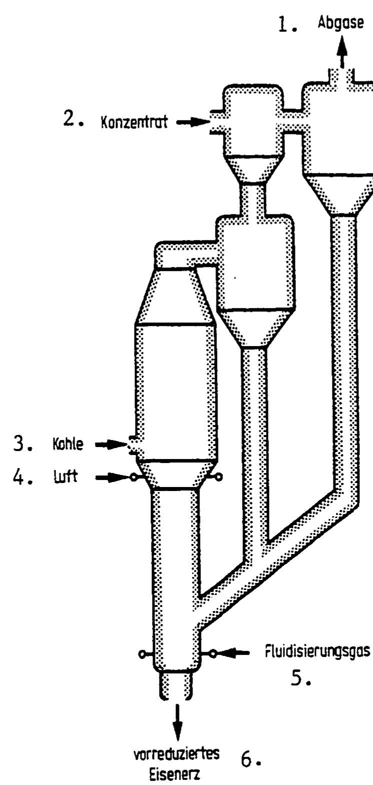

Figure 4: Diagrammatic Sketch of the Reactor and the Cyclone System for ELRED Prereduction

Key:
1. Flue gases
2. Concentrate
3. Coal
4. Air
5. Fluidization gas
6. Prereduced iron ore

monoxide-hydrogen mixture as well as the excess carbon in the form of fine-grained coke. A separate installation for generating the reduction gas is therefore not necessary.

The main component of the prereduction installation is a reactor, lined with masonry , and about 25 m high, with an interior diameter which ranges from 3 to 10 meters, depending on its capacity. The fluidizing gas is injected at the floor of the reactor, while air and the reducing agent are blown in laterally through the casing. The reduction gas is generated during the incomplete combustion of coal. Together with the fluidizing gas, it causes strong vorticity in the reactor. The flue gases conduct a major portion of the vortex layer materials out of the reactor. In a cyclone system, the solid particles are again separated, however, and are recycled into the lower part of the reactor. This system also contans an arrangement for the continuous infeed and preheating of the concentrate.

The hot flue gases from the reactor are used for various purposes, for example for preheating the air and the concentrate. After separating dust, humidity, and carbon dioxide, about 30 to 50 percent of the gas are blown in to generate the vortex layer in the lower part of the reactor. The remainder of the gas is used in a combination gas-steam power plant, to generate electricity.

Prereduced material is constantly discharged from the bottom of the reactor. This material has a high metal content and a controlled carbon content. The metal content is controlled by changing the retention time and temperature of the reactor to 60 to 70 percent.

Final Reduction Stage

A d.c. arc furnace (Figure 5) is used for the final reduction. A carbon cavity electrode is centrally affixed in the furnace, and is connected with the negative pole of the rectifying system. The positive pole is connected to the bottom electrode, which stands in direct contact with the iron melt.

The arc is completely covered by the foaming slag, and it burns perpendicular to the bath surface. The prereduced material is brought into the furnace through the center boring of the electrode. It traverses the very hot plasma zone below the electrode. Smelting, carburization, and final reduction here occur quickly and with good yield.

Before the furnace is charged, the prereduced material is mixed with suitable slag forming agents. It is then preferably brought in at a temperature of 600 to 700°C. A slag basicity of about 1.2 is maintained. The slag is withdrawn through the slag door, without interrupting operation of the furnace. It can be further processed like usual blast furnace slag.

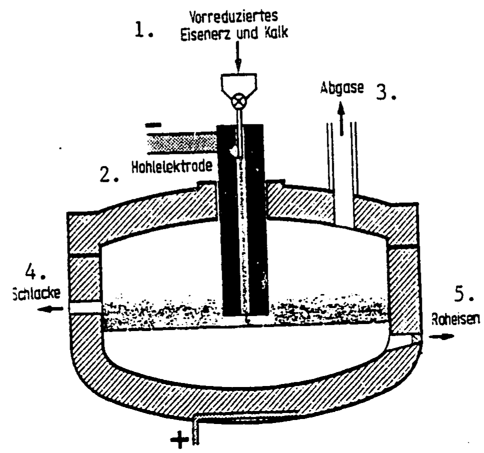

Figure 5: Diagrammatic Sketch of the d.c. Arc Furnace for ELRED Final Reduction

Key:
1. Prereduced iron ore and lime
2. Hollow electrode
3. Flue gases
4. Slag
5. Pig iron

The pig iron is tapped discontinuously, in the same manner as with a blast furnace. A liquid crater from 30 to 50 percent is left in the furnace for the next melt. The pig iron contains 3 to 4 percent carbon and about 0.05 percent each of silicon and manganese. The major portion of the sulfur and phosphorus that is brought in with the raw materials is again found in the pig iron. Sulfur is removed in the usual way by lime, while phosphorus goes into the slag during the subsequent production of steel by the basic oxygen steel-making process. Because the pig iron contains very little silicon, less slag is generated than in the oxygen refining of blast-furnace iron. When ores rich in phosphorus are used, the steel slag will therefore have a high phosphorus content and is quite useful as fertilizer.

Generation of Electricity

The energy content of the flue gases from the pre- and final-reduction stages are utilized in a combined-cycle power plant, which contains a gas and a steam turbo set. This results in high efficiency, even for small installations. The gas turbine is run with purified gas from the prereduction stage. It delivers its hot exhaust gases to an exhaust gas steam generator. The gas from the final reduction stage is also used to generate steam. The energy generated in the combined-cycle power plant covers the entire electrical need of the process. Furthermore, it will deliver a small excess (300 to 400 kWh/t pig iron) into the mains.

The rectifier of the arc furnace is fed by a transformer, which is connected to the public mains. In this way, optimal security is guaranteed even during operating disturbances in the reduction stages or in the combined cycle power plant.

Control

All system components of the ELRED method can be controlled easily and will small time constants. Since high availability is also expected from them, uniform operation must be possible without the intermediate storage of prereduced material.

Economic Perspectives

In order to be able to determine the inherent costs of the ELRED method, in comparison to other methods for pig iron production, extensive investigations were carried out.

In those investigations, the following process combinations, among others, were compared with one another:

Case	Pig Iron Production	Steel Production	Raw Materials	Energy Medium
1	Blast furnace	LD-converter	Pellets, low phosphorus content	Coke, procured externally
2	ELRED method	LD-converter	Concentrate, medium phosphorus content	Small coal
3	Shaft furnace (sponge iron)	Arc furnace	Reduction pellets	Heavy oil

Installations were investigated with an annual productive output of 450,000 tons pig iron, and particularly in the "ARA-area" (Amsterdam-Rotterdam-Antwerp). This area was chosen, because here the raw material prices for different process could be easily and reliably determined. Three reasons favored the choice of capacity: On the one hand, at the time the study was performed, Stora Kopparberg operated a blast furnace in Finland, which had just this capacity, and whose consumption data could be compared with those of Japanese blast furnaces. As a result, the precise costs for a really efficient blast furnace of this size could be determined. Secondly, the literature contains detailed specifications concerning shaft furnaces of this size. Finally, this size should be of interest for certain countries, although it does not in any way represent a maximum or an optimum for the ELRED method.

In all three cases, it was assumed that the iron plants are combined with steel plants, which produce scrap at a rate of 18 percent, and that this fraction is recycled to the steel plant as return scrap, in cases 1 and 3. Because the pig iron in case 2 had a low carbon, silicon, and manganese content, only 18 percent instead of 10 percent scrap could here be used in the LD converter. It was therefore assumed that the excess steel plant scrap could be purchased at the same price at which it was accounted in the two other cases.

Table 1 is an assembly of the estimated total costs per ton of pig iron, if the above-mentioned three process combinations are used as a basis. These data show that the ELRED/LD steel (case 2) is about 70 DM/t (20%) cheaper than the blast furnace/LD steel (case 1) and is even about 110 DM/t (32%) cheaper than the shaft furnace/arc furnace steel (case 3).

Table 1: Overall Steel Production Cost in DM/t (as of Late 1978)

	Case 1 Blast Furnace (Pellets) + LD	Case 2 ELRED + LD	Case 3 Shaft Furnace (Sponge Iron) + Arc Furnace
Raw Materials[1)]	98	64	114
Energy[2)]	103	32	91
Additional Costs[3)]	71	72	98
Capital Costs[4)]	74	87	84
Unanticipated Costs	-	20	-
Total Steel Production Costs	346	275	387
Relative Total Costs in %	100	80	112

1) Concentrate or pellets, alloy elements, cooling pellets, scrap

2) Coke, coal, oil, minus credit for in-house energy production, but adding electrical power costs in the steel plant (33 DM/t).

3) Labor costs (operation, repairs, maintenance), electricity, electrodes, lime, oxygen, fuels, desulfurization (for ELRED).

4) For iron and steel production.

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INDUSTRIAL TECHNOLOGY

DEVELOPMENTS IN NEW PLASMA PROCESSES DISCUSSED

Duesseldorf STAHL UND EISEN in German 10 Mar 80 p 228

/Unattributed article/

/Text/ The Swedish steel producer SKF depends on the utilization of very pure starting materials for its production of special steels. For this reason, the Wiberg-Söderfors method for producing iron sponge was operated for more than 25 years in Hofors. Because of its high energy demand, and because of its low output, this operation is now no longer economical. During the last ten years, possibilities were therefore explored for replacing this process.

In a plasma arc, large quantities of heat can be transferred to a gas, with high efficiency, at high temperatures, and under reducing conditions. Consequently, the development of a plasma gas reformer was pursued. Such a device can convert coal dust or hydrocarbons, together with the recycled flue gas of the reduction system, into fresh reduction gas. A small portion of the recycled gas is here heated to 4,000 to 5,000 degrees K in the plasma burner. The major portion of the recycled gas, as well as coal or oil, are directly introduced into the emerging plasma flame. A reduction gas at about 850 degrees C emerges from the subsequent reaction chamber. The gas converter has up to now been tested with liquified gas, heavy oil, and with a coal-oil slurry. Reduction gases with less than 3 percent CO_2 were produced without difficulty.

In the middle of 1979, it was decided to convert the old Wiberg installation in Hofors, and to equip it with a plasma gas converter. The plasma-red method was used, and the output was to be increased from 25,000 tons sponge iron per year to 70,000 tons per year. About 20 percent of the recycled flue gas were purified, were compressed to 4 bar, and were used as plasma gas. An energy consumption of 160 kg hydrocarbon and 735 kWh/t Fe was expected. CO_2 and H_2O can also be washed out, in order to save electric energy.

Besides the plasma-red method, a smelting reduction method was developed for generating liquid pig iron. This method is called "Plasmamelt".

This method promises to be economical even for smaller blast furnaces. The plasmamelt method is to be tested out on a shut-down blast furnace with an output of 60,000 tons pig iron/year at a cost of about 75 million skr.

The plasmamelt process combines a prereduction stage in a fludized bed and a final reduction and smelting stage, using a gas plasma. The prereduced concentrate, together with coal dust or oil, is converted to liquid pig iron, in the plasma flame in a shaft with a coke filling. The gas is withdrawn from the shaft and is used in the prereduction stage. With a prereduction level of 40 percent, the energy consumed amounts to 1100 kWh electrical energy and 215 kg coke per ton of pig iron.

It is expected that the Swedish government will make available funds for the construction and testing of an operating system.

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END